FY05 Goal – Study of Low-Strength Mortar and Flowable Fill Containing Recycled Material

- Develop Guidance Document

Introduction

Low strength mortar is also known as flowable fill, Controlled Low Strength Material (CLSM), flowable mortar, lean-mix backfill, and controlled-density fill. The Ohio Department of Transportation specification refers flowable fill as low strength mortar backfill material. But the term Controlled Low Strength Material is more general, covering more types of fill materials. In this report, the above names are used interchangeably.

Low strength mortar flows like a liquid, sets like a solid, is self-leveling, and requires no compaction or vibration to achieve maximum density. Low strength mortar is a family of artificially made backfill materials, with in-place properties that are between concrete and dense soil. It should not be considered as a type of low strength concrete, but rather a self-compacted backfill material that is used in place of compacted fill. Generally CLSM mixtures are not designed to resist freezing and thawing, abrasive or erosive forces, or aggressive chemicals. Non-standard materials may be used to produce CLSM as long as the materials have been tested and found to satisfy the intended application.

The primary application of CLSM is as a structural fill or backfill in lieu of compacted soil. CLSM is ideal for use in tight or restricted-access areas where placing and compacting fill is difficult. If future excavation is anticipated, the maximum long-term compressive strength should generally not exceed 300 psi. Applications for flowable fill include backfill in sewer and utility trenches, building excavations, bridge abutments, and conduit trenches as well as miscellaneous uses such as retaining wall backfill and filling abandoned wells, sewers, manholes, and underground storage tanks. Because it does not

require compaction or vibration, flowable fill can be a cost-effective fill material. According to the American Concrete Institute 229-94 report, "Controlled Low Strength Materials (CSLM)" advantages of flowable fill include reduced labor and equipment requirements because it is self-leveling; versatility in terms of flowability, strength, and setting times; higher load-carrying capacity than compacted soil or granular fill; reduced excavation costs; and improved worker safety because flowable fill can be placed without workers entering the trench. The following applications are intended to present a range of uses for CLSM.

- Backfills
- Structural fills
- Insulating and isolation fills
- Pavement bases
- Conduit bedding
- Erosion control
- Void filling

Although CLSM generally costs more per cubic yard than most soil or granular backfill materials, its many advantages often result in lower in-place costs. In fact, for some applications, CLSM may be the only reasonable backfill method available. American Concrete Institute 229-94 report listed a number of advantages to using CLSM.

- Readily Available – Using locally available materials, ready mixed concrete suppliers can produce CLSM to meet most project specifications.
- Easy to deliver – Truck mixers can deliver specified quantities of CLSM to the jobsite whenever the material is needed.
- Easy to place – Depending on the type and location of void to be filled, CLSM can be placed by chute, conveyor, pump or bucket. Because CLSM is self-leveling, it needs little or no spreading or compacting. This speeds construction and reduces labor requirements.

- Versatile – CLSM mix designs can be adjusted to meet specific fill requirements. Mixes can be adjusted to improve flowability. Add more cement or fly ash to increase strength. Admixtures can be added to adjust setting times and other performance characteristics. Adding foaming agents to CLSM produces a lightweight, insulating fill.
- Strong and durable – Load-carrying capacities of CLSM typically are higher than those of compacted soil or granular fill. CLSM is less permeable, thus more resistant to erosion. For use as permanent structural fill, CLSM can be designed to achieve 28 day compressive strength as high as 1200 psi.
- Can be excavated – CLSM having compressive strengths of 50 to 100 psi is easily excavated with conventional digging equipment, yet is strong enough for most backfilling needs.
- Requires less inspection – during placement, soil backfill must be tested after each lift for sufficient compaction. CLSM self-compacts consistently and does not need this extensive field testing.
- Allows fast return to traffic – Because many CLSM's can be placed quickly and support traffic loads within several hours, down time for pavement repairs is minimal.
- Will not settle – CLSM does not form voids during placement and will not settle or rut under loading. This advantage is especially significant if the backfill is to be covered by a pavement patch. Soil or granular fill, if not considered properly, may settle after a pavement patch is placed and forms cracks or dips in the road.
- Reduces excavation costs – CLSM allows narrower trenches because it eliminates having to widen trenches to accommodate compaction equipment.
- Improves worker safety – Workers can place CLSM in a trench without entering the trench, reducing their exposure to possible cave-ins.
- Allows all weather construction – CLSM will displace any standing water left in a trench from rain or melting snow, reducing the need for dewatering pumps. To place CLSM in cold weather, heat the material using the same methods for heating ready-mixed concrete.

- Reduces equipment needs – Unlike soil or granular backfill, CLSM can be placed without loaders, rollers or tampers.
- Requires no storage – Because ready-mixed concrete trucks deliver CLSM to the job site in the quantities needed, storing fill material on site is unnecessary. Also, there is no leftover fill to haul away.
- Makes use of a by-product – Fly ash is a byproduct produced by power plants that burn coal to generate electricity. Spent foundry sand, which may be used as a sand substitute within the mixture, is a large waste stream generated by foundry operations. CLSM containing fly ash benefits the environment by making use of this industrial byproduct material. Using spent foundry sand in the CLSM mix significantly enhances the beneficial reuse impact of a project.

Low strength mortar hardens and develops strength. Three levels of strengths are generally specified corresponding to removal with hand tools (less than 100 psi), removal by mechanical means (less than 200 psi), and removal with power equipment (less than 1200 psi). The recommended 28-day compressive strength range is 100 to 200 psi. Low strength mortar is typically placed using ready-mix concrete trucks. In many cases, these materials are designed so that they are comparable in strength to the surrounding soil after hardening, making excavation at a later time possible.

Recommendation

The use of recycled materials by federal agencies is very strongly encouraged by the USEPA Comprehensive Procurement Guidelines. The flowable fill or CLSM guidelines promote the reuse of both fly ash and spent foundry sand. They also provide mix specifications to improve the performance of the CLSM in applications. The use of this material is strongly encouraged when it meets project requirements.

The past problems can be avoided by following guidelines and enforcing specifications throughout the project. On May 21, 2002 Mr. Michael Quintin published NASA GRC "Guidelines for Specifying the use of Spent Ferrous Foundry Sand in Flowable Fill Applications" which include the appropriate use of spent foundry sand (Appendix A).

These guidelines also addressed quality assurances to avoid problems with the CLSM mix and/or later disposal restrictions. A memo dated April 11, 2002 (Appendix B) also provides some procurement details. I recommend that these guidelines be used, with the following additions.

The past problems, both with excess strength and water quality, relate to the mix specifications. Excessive binders (cement and/or fly ash) can create too much strength for the application. The use of high lime or slag cement, or other use of ground granular slag in the mix, can create a high pH value in contact water – a potential NPDES violation. These problems can be avoided by specifying an appropriate mix, testing the mix, and not accepting deviations from the specifications. The past problems were most likely caused by significant deviations from recommended mixes, not just minor operational variability. This document refers to several very reliable mix specifications, including the USEPS CPG, the Ohio DOT, the PENN DOT and the Iowa DOT specifications. The DOT specifications relate to the climate at NASA GRC, and should serve well as guidelines at GRC.

The use of any high-lime cement, slag cement, and/or ground granular slag is not recommended for any situation where the fill may come into contact with water when in place. These materials are not included in the above specifications.

Enforcing the testing and specifications may be necessary to avoid future problems. A memo dated April 11, 2002 (Appendix B) also provides some procurement details.

Walter M. Kocher